CHAPTER 4

Findings and Future Directions

Introduction

Over the years, California has devoted substantial efforts toward environmental protection and resource management. While the state has been, in many instances, a national and international leader in developing and implementing solutions to its environmental problems, there are very few mechanisms to quantify and track the impacts of these solutions on the environment. As environmental issues and alternatives to solving them become more difficult and complex, it is increasingly critical to have the capability to recognize problems early, and to devise strategies based on a consideration of the full range of possible environmental consequences.

Environmental indicators can provide an objective, scientifically-based representation of the condition of the environment. They can be used in communicating information to the public. They can help improve the understanding of the state of the environment, how its different components might interact, and how it might be affected by human activities. Because of this, environmental indicators are powerful tools in "results-based management systems," in which information about the environment is considered in strategic planning, priority setting, resource allocation and other decision-making processes.

The Environmental Protection Indicators for California (EPIC) Project has produced this report after an intensive year's effort to build a framework for an environmental indicator system for California. This framework lays out the process and criteria for indicator development, and presents an initial set of indicators.

Developing the Indicator Selection Process

This first task in constructing the EPIC framework was to establish a process that will guide the identification, selection and development of the environmental indicators to be included in the system. This process is described in Chapter 2. It requires the application of criteria designed to ensure that the indicators are scientifically valid, meaningful, and useful in decision-making; the process also classifies indicators based on the availability of data. Some flexibility was incorporated into the process to allow the use of certain data sets that do not strictly meet the criteria in the absence of other data, provided that a reasonable approximation of the parameter of interest can be presented.

The scope of the initial effort covered issues that relate to the mission of Cal/EPA and its constituent entities, and to areas of overlapping jurisdictions with the Resources Agency and the Department of Health Services. Indicators relevant to the central missions and mandates of the latter two entities are the responsibility of those agencies, and will be addressed by their strategic planning functions. Indicators for more complex areas such as environmental justice, sustainability and pollution prevention will be addressed in subsequent years. Clearly, these areas include some high priority issues for California;however, developing indicators that are in line with the state's goals in these areas will require more time. Different types of environmental data will need to be integrated with non-environmental

information on such factors as social, economic, demographic, and others. In addition, the environmental indicators may need to be refined to a desired level of detail (such as at a community level).

The indicators in this report were developed through a close collaborative process involving staff in Cal/EPA, the Resources Agency and the Department of Health Services, with input from an external stakeholder group, an interagency advisory group of policy-level state agency representatives, and participants at a two-day conference. The collaborations offered excellent opportunities to build or strengthen partnerships among the participants and the organizations they represent. The project brought together Cal/EPA and the Resources Agency, the two cabinet-level agencies responsible for protecting and managing California's environmental resources.

Encouraged by the successful use of environmental indicator systems (notably those in New Jersey, Florida, New Zealand and the Netherlands) to guide decision-making, Cal/EPA has committed to moving toward a results-based management system. While this new direction has been generally well received, it will take time before it is fully implemented. It will require integrating indicators into goals, milestones and strategies, then using the indicators to track progress. Using indicators will necessitate a good understanding of the significance of the trends shown by the indicators, and of the factors that influence them. For example, an indicator showing little or no change in its trend may suggest that efforts are no longer needed to address the problem; on the other hand, it is more likely to suggest that the efforts to address the problem have been effective in keeping it under control, and discontinuing these efforts would be detrimental to the environment. Further, such a trend may actually represent tremendous strides in addressing a problem, particularly when driving forces, such as population growth, are taken into account. Cal/EPA has adopted eight overarching strategic goals (listed in Chapter 1), progress toward six of which can be tracked with the use of environmental indicators.

Indicator development began with a concerted effort to identify the significant environmental issues of concern confronting California – issues that need to be better understood by quantitatively characterizing them using indicators. The issues were then organized in a manner that facilitated the identification of possible indicators and the data with which they can be developed. For this report, the organization parallels the areas of responsibilities of Cal/EPA's environmental programs. This organization may have limited the definition of issues and identification of possible indicators to areas covered by existing mandates, activities, and regulatory provisions of Cal/EPA. For example, the selection of Type III indicators (i.e., indicators requiring data) may have been biased toward data that can be collected by simply expanding existing efforts, or data based on preliminary or one-time efforts undertaken by a regulatory program.

This report takes an important first step in presenting, in a single document, a collection of environmental indicators derived from various sources, and spanning a wide range of significant environmental issues confronting California. By examining the indicators individually and collectively, environmental programs can gain a better awareness of what is known about the condition of the state's environment, what information is required to understand certain issues, what the potential problem areas might be, and possible ways of addressing them and measuring success.

Selecting the Indicators

Significant challenges were encountered during the process of developing the initial set of indicators. Indicators must meet all of the following primary criteria (discussed in Chapter 2):

- **Data quality** (the indicator is based on scientifically valid data collection)
- **Representativeness** (the indicator reflects the environmental issue for which it was selected)
- **Sensitivity** (the indicator can detect meaningful differences in environmental conditions)
- **Decision support** (the indicator supplies information that can support decision-making)

The initial set of environmental indicators relies heavily upon established environmental monitoring and data collection activities in California. Although there is extensive data collection in the state, the available data are of variable quality for indicator development. Environmental data collection has generally been reactive, often carried out to characterize known or suspected problems, or to formulate and test the effectiveness of regulatory strategies. In many cases, data were not collected with the intention of surveying conditions to establish status and trends. This results in data that reflect conditions at a contaminated site or a polluted area (often called a "hot spot"), rather than providing an assessment of environmental conditions at a region or of the state as a whole. Most frequently, when the site is cleaned up, or the pollution abated, data collection ceases. This manner of data collection generally does not support indicator development. To meet the data quality criterion for indicator selection, the data must be representative of the issue or system, and must be based on systematic, ongoing environmental monitoring, such as that conducted under the decades-long statewide monitoring for criteria air pollutants.

Identifying representative indicators using existing data was also a challenge. A significant portion of current data collection focus on tracking activities such as permits issued, grants awarded, or violations committed. This type of data generally do not support environmental indicators because they convey little about the condition of, or effects on the environment. In other cases, it was difficult to identify which indicator would best represent the issue. For example, selection of sentinel or indicator species to represent the condition of a particular ecosystem requires significant knowledge of the system of interest. Expertise was not always available, and time constraints precluded consulting outside experts for input on all issues.

This initial report primarily presents indicators of statewide trends. While statewide indicators may provide a good overall summary, they generally do not represent regional conditions. California's environment is very diverse, and includes many unique regions and ecosystems (such as Lake Tahoe, Death Valley, the San Francisco Bay Delta System, and the California/Baja California, Mexico border region) that cannot be adequately characterized by statewide indicators. Indicators specific to air basins, watersheds and ecological regions can better reflect environmental change, and provide more relevant information to support decision-making. Examples of regional indicators are air basin-specific trends in emissions or ambient levels of criteria air pollutants (see Air Quality section in Chapter 3).

The sensitivity of the measures used for indicators was the third primary criteria. The sensitivity of the data used in this first set of indicators spans a wide range. Some data possess a high degree of sensitivity. Other data were affected by confounding variables and had relatively poor sensitivity. For example, economic activity influenced many of the measures used; therefore, the observed trends may be as much a reflection of changes in the economy as they are a reflection of real changes in the environment. Explanations of how these confounders affect the trends in the indicator were included in the narratives for the indicator whenever possible. In many cases, however, the influences of these variables are not well understood.

The ability of the indicators to advise decision-making is dependent on the degree to which they meet the previous three criteria. If concordance is weak, the indicators could provide misleading information. As the quality, sensitivity, and representativeness of data and the indicators derived from them improve over time, the indicators will become more useful in decision-making. Further, the ability of environmental programs to use the indicators as considerations in decision-making depends upon how well the factors that affect the environmental conditions are understood. This will require enough of an understanding of the system in question to determine how human activity (governmental actions, actions by the regulated community, or societal actions) can effect changes in pressures upon the environment, how these changes can in turn affect ambient environmental conditions, and finally, how environmental conditions can impact human or ecological health.

The EPIC process also specifies secondary criteria that, although not essential, made an indicator more desirable. These criteria address whether an indicator can be used to anticipate changes, can be compared to indicators in other

programs or systems, is cost-effective, and is based on, or can be compared to, a benchmark or reference value. These criteria were applied to indicator selection to the extent it was possible to do so.

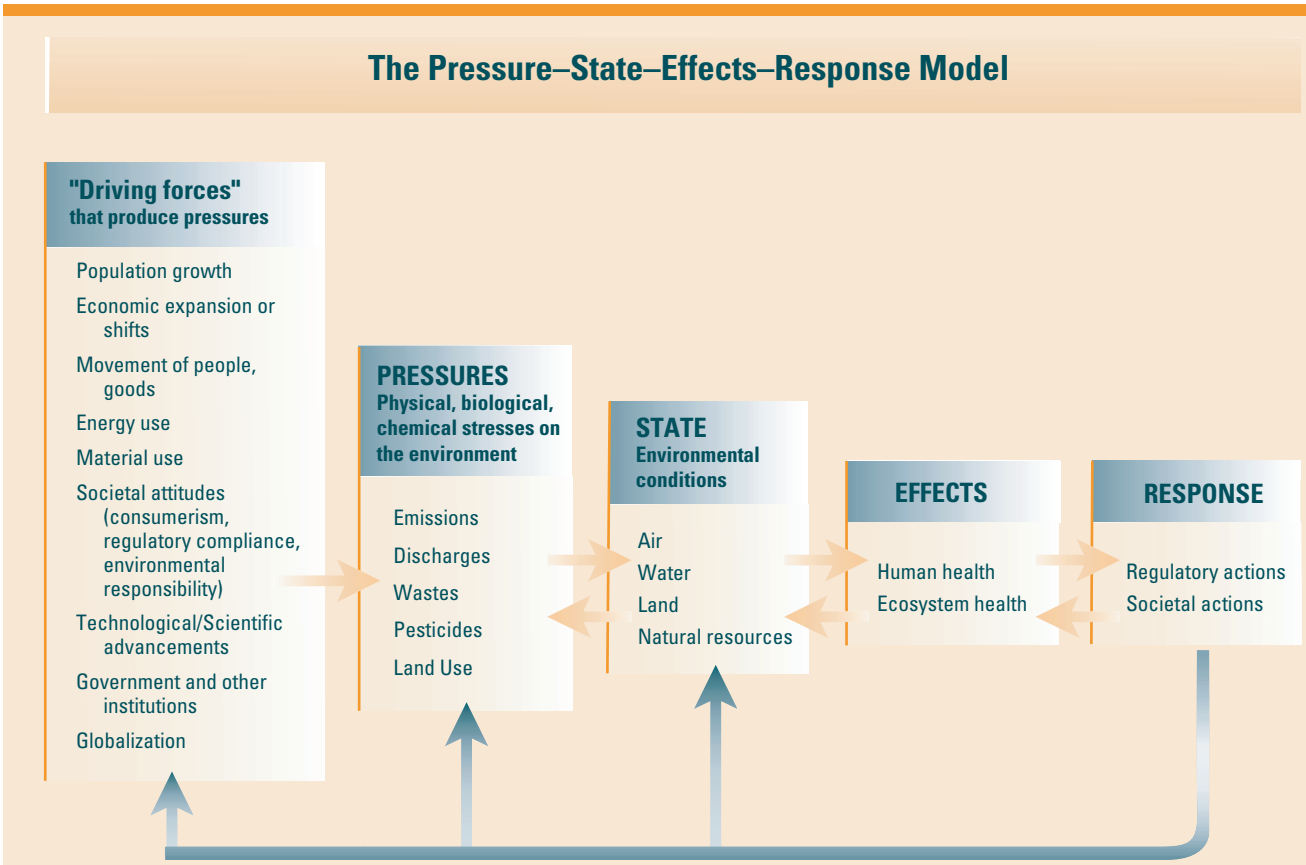
The Indicators

Valuable insight can be gained by viewing the indicators with reference to the "pressure-state-effects-response" conceptual model (see diagram on the following page), extended to include the driving forces that can produce pressures upon the environment. Population growth is a driving force that can create significant pressures upon the state's environment and natural resources. Already the most populated state in the country, California continues to grow faster than the rest of the nation, having added over half a million people to its population every year for the past four years. California is currently home to an estimated 35 million people, with more than three-quarters of the population living in 12 of the state's 58 counties. Population growth impacts the other major forces that drive change, such as the economy, the consumption of energy and materials, and the movement of people and goods. All of these forces can influence one another, as well. For example, increased economic activity creates jobs that draw more people into the state. The increased production of goods increases energy and material consumption and the need to transport goods. Changes in the nature of the California economy, such as the growth of service-oriented businesses and the information technology industry, can produce a different set of pressures. Recognizing the trends in the driving forces that create the physical, chemical and biological pressures on California's natural resources provides a context for better understanding the trends revealed by the environmental indicators. Many of the background indicators presented in this report portray a partial picture of the trends in the "driving forces."

Despite the increasing strain produced by the driving forces on California's environment, certain environmental indicators show trends that are consistent with the state's goals of improving, restoring or preserving the environment. For example, emissions and ambient levels of criteria air pollutants generally show declining trends. Contaminants in drinking water are rarely found at levels exceeding regulatory standards. Increasingly, a greater percentage of all solid waste is being diverted from landfills, and less hazardous waste is produced per unit of economic activity. These successes can in part be attributed to California's environmental programs.

Other indicators show a lack of improvement or a worsening of environmental conditions. The population of winter run chinook salmon in the Central Valley has declined to extremely low levels. The clarity of Lake Tahoe, an indicator of overall lake function, continues to decline. The population of the desert tortoise, a federally designated endangered species, has declined significantly since 1980. In some air basins, levels of inhalable particulate matter (PM10) have not been significantly reduced over the last ten years.

Finally, additional challenges stem from a lack of data with which to gauge the status of certain environmental issues. For example, status and trend data are lacking on such issues as indoor air quality, the impacts of pesticide use on air and water quality, the impacts of environmental exposures on human health, and many aspects of the state's natural resources. When viewed against the "pressure-state-effects-response" conceptual model, most of the indicators presented in this report fall into the "pressures" or "state" categories. Indicators of "effects" on human and ecological health are few and, over time, more indicators in this category should be included. However, human health is influenced by the interaction among exposures to environmental contaminants, genetics, and lifestyle factors such as smoking, diet, and exercise. Until adequate scientific information is available to define and quantify how these factors contribute to disease, indicators of environmentally-related health effects will be difficult to develop. In the meantime, a better understanding of human exposures to harmful environmental contaminants may be gained from tracking data on the levels of environmental contaminants in the human body.



Issue Area-Specific Findings

From the initial set of indicators, some key findings in several areas have become apparent. What follows are summaries of these key findings and future directions for each major issue category in this report.

Air Quality

Through diligent monitoring efforts, the California Air Resources Board has consistently collected air quality data that are ideally suited for developing indicators. The extensive monitoring by the state originally arose out of the need to tackle some of the worst urban air pollution in the country. The significant areas of poor air quality are regional in scope, and located in the major urban air basins of the state (South Coast, San Joaquin Valley, Sacramento Valley, San Francisco Bay Area, and San Diego Air Basins). Thus, a regional approach was taken to monitor air quality as methods were implemented to reduce air pollution. Reducing air pollution, particularly in urbanized regions, is a continual challenge as the population of the state increases (see Population Demographics and Transportation background indicators).

Major efforts have been made in reducing air pollutants over the last 20 to 30 years. The largest benefits have resulted from reductions in emissions from gasoline-fueled vehicles, one of the main sources of air pollution in urban air basins. The major findings of the air indicators include:

- Carbon monoxide has ceased being a major air pollutant in all areas of the state, except in some border areas with Mexico and in the South Coast Air Basin, which have had infrequent exceedances of the standard.

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- While ozone levels still intermittently exceed the state standards in California's five major air basins, total yearly exposure to ozone has been reduced by over 75 percent in the most polluted regions over the last 10 to 15 years.
- Levels of particulate matter (PM10) have been only modestly reduced (by about 20 to 40 percent) in some major air basins, and not significantly reduced in a few others. Urban sources of PM10 currently represent one of the biggest challenges in reducing air pollution.

Efforts initiated on the following air quality issues will support the development of indicators in the future:

- A consistent measure of visibility for both urban air basins and pristine regions.
- Statewide air levels and composition of PM2.5 (particulate matter with an aerodynamic diameter of 2.5 microns or smaller). This fraction of particulate matter can be inhaled most deeply in the lungs and likely represents a better indicator of potential human injury than the PM10 fraction that is currently collected.
- An understandable presentation of cancer risk based on regional exposure to toxic air contaminants. There are a number of considerations in the development of cancer risk estimates that need to be addressed to provide a full appreciation of this complex issue.

To support the development of future indicators on significant air quality issues, future efforts will focus on data collection and evaluation, as described below:

- Although a substantial amount of information has been generated for indoor air quality, there are no monitoring data for developing indicators that define the scope and magnitude of the problem. Indoor air quality is of particular concern because it may now present a greater threat to human health than outdoor air pollution.
- The development of the toxic air contaminant emission inventory indicator will facilitate the implementation of emission reductions from stationary sources and other area-wide sources.
- The development of community-based indicators for air quality will allow the identification of specific communities that are disproportionately exposed to higher levels of air pollutants.
- The development of population-based indicators will provide more meaningful information to the public about the number of people exposed to unhealthy levels of air pollutants.

Water

Water is one of California's most precious resources, serving a multitude of needs, including drinking, recreation, supporting aquatic life and habitat, and agricultural and industrial uses. It provides an essential lifeline for the state's burgeoning population of approximately 35 million. The management, assessment, and protection of California's water for all beneficial uses are of paramount concern for all of California's inhabitants.

Indicators were developed to track: (1) water quality, and (2) water use. Water quality indicators are presented according to the various beneficial uses of water resources. Such uses include drinking (and other household uses), crop irrigation, industrial and recreational uses, and fish and wildlife habitat. Water use indicators reflect trends in quantities of water used.

Water quality

The development of water quality indicators was limited by the quality of available data. For ambient waters, a sustained, comprehensive and consistent data collection effort has been lacking. To address this deficiency, the State Water Resources Control Board has instituted the Surface Water Ambient Monitoring Program (SWAMP) and the Groundwater Ambient Monitoring and Assessment (GAMA) Program. With the promise of these programs to reinforce monitoring and assessment activities, a more robust and complete set of indicators will become available in the future. Based on the best information currently available, the most significant findings of the water quality indicators are presented below:

- Sources of drinking water continue to show improvement in quality. Monitoring of about 20,000 sources shows that the number of exceedances of drinking

water standards in 2000 was less than half of the value of the late 1980s. Since 1984, less than one percent of the 20,000 municipal drinking water sources in the state exceeded drinking water standards.

- The potential for groundwater contamination from leaking underground fuel tanks is declining. This progress is due to the cleanup of leaking sites and the upgrading of containment features of operating tanks. While leaking tanks still represent a widespread problem (there are about 17,000 sites in 2000), the number of sites has decreased by about 20 percent from 1995 to 2000. A small decline occurred in the number of leaking tanks within 1,000 feet of public drinking water sources.
- Coastal beach closures due to bacterial contamination increased 15 percent from 1999 to 2000. With the recent standardization of beach posting protocols, more consistent and meaningful trends will be available in the future.
- The number of sewage and petroleum spills and releases increased by about 33 percent from 1997 to 2000, from 1,445 to 1,918. The number of sewage spills alone increased by 76 percent.
- Data to present trends in surface water quality – in terms of the extent by which surface waters support beneficial uses (such as aquatic life protection and swimming) — are not available. A snapshot of the 2000 assessment is presented. Trends will result with implementation of new monitoring programs.
- Commercial shellfish growing waters continually meet the regulatory standard for fecal coliform bacteria during open harvesting periods.
- Only 12 percent of ocean waters, and 36 percent of bay and estuary waters have been assessed to determine the safety of consuming sport fish caught in these waters. These assessments show that the extent of ocean miles from which fish can be safely consumed once a week increased from 1990 to 1995, and remained the same in 2000. The extent of bay and estuary acres from which it is safe to eat fish once a week decreased in the same time period.

Water quality indicators under development are as follows:

- Leaking underground fuel tanks represent only a portion of the groundwater contamination problem. It is expected that a more complete picture of the number and extent of groundwater contamination sites, including contamination from leaking landfills and other unauthorized releases of contaminants to groundwater, will be addressed by future indicators.
- Beneficial uses of surface waters (lakes, rivers, etc.) will be assessed more extensively under a new program (SWAMP). These assessments will provide data for indicator development in the near future.

A possible area for indicator development in the future is the safety of eating fish caught from inland waters, as described below.

- To date, the inland waters assessed to determine the safety of consuming caught fish are a very small fraction of all waters where fishing occurs. A program similar to the Coastal Fish Contamination Program is needed to collect the data necessary to make this a useful indicator. Currently, this indicator can only be updated when special or one-time studies generate adequate data for assessment of rivers or lakes.

Water supply

- Urban uses of water are increasing; agricultural uses are leveling off. This change is primarily due to the increasing population and urbanization of agricultural lands.
- Recycling/reuse of municipal wastewater increased by 50 percent in 13 years. In 2000, the amount of recycled water was equivalent to the annual water supply needs of over 1,600,000 people.

Land, Waste and Materials Management

Waste is a by-product of human activity. If not managed properly, solid and hazardous wastes can exact considerable costs, in terms of lost resources, environmental contamination, and adverse effects on human and ecological health. Waste-related data are tracked by the California Integrated Waste Management Board (solid

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waste), and by the Department of Toxic Substances Control (hazardous waste). These data are collected under existing programs aimed at promoting waste reduction, recycling, diversion of solid waste from landfills, and waste management and remediation efforts to prevent or minimize environmental contamination and human exposures to hazardous chemicals. The indicators for waste show that:

- Although Californians are generating more solid waste, more of the waste is being diverted from disposal in landfills. Since 1989, the amount of solid wastes disposed of in landfills has decreased by about 13 percent. At the same time, diversion, which reflects recycling, reuse and waste reduction, has increased by over 500 percent. Much of the impetus for the diversion and recycling trends was provided by the Integrated Waste Management Act, which spurred the implementation of waste prevention, recycling and composting programs at the local level to meet goals for waste diversion that were established by statute.
- Similarly, waste tire disposal has been declining over the past decade, while diversion has been increasing. Approximately 23 million waste tires were diverted from disposal in 2000, more than double the number in 1990. Diversion appears to be influenced by the development of viable markets for waste tires, for such uses as fuels at cement kilns; use in asphalt for road construction; and pyrolysis (thermal degradation in the absence of oxygen) to produce oil, gas, and steel.
- The amount of hazardous waste generated and shipped for treatment or disposal over the past seven years has increased by 16 percent, from 2.3 million tons in 1993 to 2.7 million tons in 2000. However, when economic activity is taken into consideration, waste generation has declined by 30 percent.
- Disposal in landfills and recycling are the predominant fates of most hazardous waste shipments. In 2000, almost 40 percent of the shipments were destined for landfill disposal, and over 33 percent for recyclers. Both landfill disposal and recycling showed increases over the past seven years (65 percent and 19 percent, respectively).
- There are no clear trends for hazardous material incidents, for soil cleanups at hazardous waste sites, and for the number of contaminated sites.
- Information on the magnitude and scope of environmental contamination resulting from unsound management of solid and hazardous waste is very limited and fragmented.

Although data are now collected on the following, additional effort will be needed to develop meaningful indicators reflecting:

- Amounts of hazardous waste generated, segregated as federal hazardous wastes and non-federally regulated (commonly referred to as "California-only") hazardous waste. Currently, trends in hazardous waste generation in California cannot be compared with those in other states or the rest of the nation. California regulations are broader than federal law in defining what constitutes hazardous waste, such that certain wastes that would not be regulated as hazardous under federal law are regulated as such in California.
- Amounts of hazardous wastes exported by California to other states and nations, as well as the amounts imported into the state.
- Cleanups of illegal solid waste disposal sites and illegal tire sites.

Future efforts will attempt to address the following issues and indicators:

- Site contamination, including the movement of contaminants from soil to air or water, and the impacts of remediation efforts on environmental quality and reduction of potential risk.
- Quantifying the impacts of households on the overall solid and hazardous waste streams. Of particular interest are the generation and handling of household hazardous wastes, and the diversion of organic wastes from landfills through composting.

Pesticides

As hazardous substances that are deliberately introduced into the environment to achieve a desired outcome, pesticides represent a unique subset of environmental issues. Because of their inherent toxicity (they are designed to control or eradicate a target organism), pesticides have the potential to adversely impact human and ecological health. The data collection and environmental monitoring conducted by the Department of Pesticide Regulation (DPR) is used to determine whether the regulatory controls for a given pesticide need to be modified, or use of a pesticide prohibited, in order to prevent further environmental contamination and, ultimately, human exposures to pesticides at harmful levels. These data have provided the basis for the indicators presented in this report. The pesticide indicators show that:

- Since 1989, less than two percent of produce sampled contained illegal pesticide residues. In most cases, the residues found were for pesticides for which a regulatory standard ("tolerance") has not been established for the commodity in which it was found. Monitoring helps ensure that produce offered for sale complies with regulatory standards for pesticides in produce. Tracking pesticide residues is an important tool to enforce regulatory standards designed to prevent potentially harmful human exposures to pesticide residues.

- Reported illnesses related to occupational pesticide exposures declined by about 60 percent over the past decade, occurring less frequently in agricultural settings. The data on pesticide-related illnesses are from physicians, who are mandated by statute to report such occurrences, supplemented by DPR reviews of occupational illness reports in the state workers' compensation system.

- The presence of pesticides in groundwater can only be partially characterized at this time. The cumulative land area where pesticide use is regulated in order to protect groundwater has increased from 141 sections in 1998 to 459 sections in 2000. (A section of land is a one-square mile area, based on the U.S. Geological Survey Public Land Survey coordinate system.) However, this trend is largely driven by the extent of well monitoring conducted annually, and the regulatory response to the discovery of groundwater contamination, rather than actual environmental conditions. A second groundwater indicator, in two counties (Tulare and Fresno) that are vulnerable to groundwater contamination, shows a stable trend in the concentrations of simazine (a widely used pesticide in the area) and its breakdown products in a network of 70 domestic wells. This indicator, however, cannot be extrapolated to other areas or other pesticides.

- Limited information is available on the magnitude and scope of the impacts of pesticides on surface waters. Current surface water monitoring efforts for pesticides are only designed to characterize a particular site for a specific period of time, and these data are not generally suitable to track long-term trends.

- Available data on levels of pesticides designated as toxic air contaminants cannot be used as an indicator because there is no network of monitoring stations that sample pesticides over time. The data are from individual studies targeting a specific pesticide in areas of high use during periods of high use, and provide information in support of the possible identification of the pesticide as a toxic air contaminant.

- A meaningful indicator for pesticide use cannot be presented at this time. All agricultural pesticide use (defined broadly to include use on roadsides and other rights-of-way, parks, golf courses, and cemeteries) and structural use by professional pest control companies must be reported; however, institutional and home uses are exempt. Because aggregated use volumes in themselves only represent the potential for human health and environmental impacts, a more meaningful trend is desired. This type of information would require categorization of pesticides based on toxicity and environmental impacts, and then require integration of this information with use volumes.

- The adoption of reduced-risk pest management systems cannot be quantified at this time; however grant programs administered by DPR will provide a starting point for collection of this information.

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- Data on the ecological impacts of pesticide use are limited only to fish and bird kills, and the reporting and maintenance patterns of these data sets are too fragmented to be incorporated into an environmental indicator.

Some of the areas to be explored in the future will focus on:

- Presenting data on all pesticide use (agricultural, institutional, home use and others) in terms of potential human health and ecological impacts. Work done by others (such as those described in *An Overview of Pesticide Impact Assessment Systems based on Indexing or Ranking Pesticides by Environmental Impact*, Cornell University, 1997; posted at www.cfe.cornell.edu/risk/pri/LCL-PestRiskInd7-97.pdf) in developing appropriate weighting factors (based on toxicity, environmental fate and transport, and other considerations) will be reviewed to investigate possible approaches in the development of an indicator. This will aid in tracking the reduction in potential human risks associated with the use of reduced-risk pesticides.

- Characterizing the impacts of pesticide use on water quality, including how urban use can affect water contamination. Much of the available data, and DPR's efforts, currently focus on areas of known or suspected contamination, typically in areas of heavy agriculture. Monitoring networks may be established for both surface water and groundwater to provide an ongoing, systematic data collection system that allows for improved assessment of water contamination by pesticides. Water contamination involving pesticides that are no longer registered for use falls under the responsibility of the State Water Resources Control Board (SWRCB). The identification of possible ways to integrate the data collected by DPR and SWRCB into an indicator reflecting overall water quality impacts of pesticides will be useful.

- Investigating possible options for collecting air monitoring data on a systematic, ongoing basis to support the development of a valid indicator for pesticide levels in air.

- Investigating pesticide use data for all agricultural and commercial structural pesticide applications along with data on emission potential as the basis for an indicator showing pesticides as sources of volatile organic compounds.

- Enhancing the indicator for pesticide-related illnesses. Because of consistent problems with physician reporting of non-occupational illnesses, DPR is working with the state's Poison Control Centers to develop a better means to track pesticide-related illnesses and injuries that occur in home and other non-occupational settings.

- Compiling and analyzing existing data on fish and bird kills, and exploring alternative means and data needs for tracking the ecological impacts of pesticide use.

Transboundary Issues

California is part of the global community sharing international borders with Mexico, and state boundaries with Oregon, Nevada, and Arizona. The movement of certain pollutants by natural processes, meteorological forces, and human activities can produce environmental threats which extend beyond California's geographical boundaries. Conversely, pollutants which originate in other states, countries or ecosystems, carried by atmospheric air currents, watersheds, trade, and travel can impact California. In this report, the transboundary issues include global climate change, stratospheric ozone depletion, pollution in the California/Mexico border region, and invasive species.

The greenhouse effect is a process that harnesses light reflected from the earth's surface and warms the atmosphere. A variety of both naturally occurring and synthetic greenhouse gases (GHGs), including carbon dioxide, methane and nitrous oxides, may enhance this effect. The National Research Council (NRC) climate change analysis requested by President George W. Bush and the Third Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) conclude that the global climate is changing at a rate unmatched in the past one thousand years. The IPCC assessment cites new and stronger evidence that most of the global warming observed over the last fifty years is attributable to human

activities, and that anthropogenic climate change will persist for many centuries. However, while the NRC report generally agrees with the IPCC's Third Assessment, it does not rule out that some significant part of these changes is also a reflection of natural variability. The observed changes over the last fifty years and those projected for the future include sea level rise, higher maximum air temperatures, more hot days, fewer cold days, and greater extremes of drying and heavy rainfall. A more recent report from the NRC cites that periods of gradual change in the Earth's past were punctuated by episodes of abrupt change, including temperature changes of about 10 degrees Celsius, or 18 degrees Fahrenheit, in only a decade in some places. Greenhouse gas warming and other human alterations of the Earth's system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events.

Environmental measures have been selected to help track certain parameters of climate change and GHG emissions as they relate to California. The global climate change indicators show that:

- Compared to the rest of the United States, California emits less of the greenhouse gas carbon dioxide, when calculated per person and per unit of the economy; however, compared with other developed nations, California emits more. Moreover, California's carbon dioxide emissions per person and per unit of gross state product have been declining in the past decade, despite increases in fuel use and population growth.
- Air temperatures have gone up by approximately 1 degree Fahrenheit (1°F) in rural areas of California over the past century, compared to an increase of about 3^0F in developed urban areas. Cities have higher temperatures than less populated locations because of the "urban heat island effect" which can skew temperature readings. Global air temperatures are estimated to have increased by 0.5°F to 1.0°F since the late 20th century.
- Snowmelt from the California Sierra Nevada has decreased by 9 to 12 percent over the past century. Lower water volumes of the spring snowmelt runoff may indicate warmer winter temperatures or unusually warm springtime temperatures.
- Sea level rise provides a physical measure of possible oceanic response to climate change. Over the last century, sea levels have risen at some points along the California coast, but decreased at others. Local land subsidence and, conversely, geologic uplifting of land mass can affect tidal calculations.
- The protective stratospheric ozone layer has gradually decreased over the mid-latitudes of the Northern Hemisphere (including California and the continental U.S.) from 1979 to the early 1990s. However, the downward trend has not continued in recent years as levels of ozone-depleting substances, including bromine and chlorine, stabilize in the stratosphere. Due to additional atmospheric processes that occur in the Polar Regions, ozone depletion in these regions is generally greater than over California.

The indicator for California/Baja California, Mexico border issues shows that:

- Air monitoring stations in the San Diego/Tijuana and Imperial Valley/Mexicali border areas reported peak ozone, carbon monoxide and particulate matter (PM10) concentrations that continue to exceed state air quality standards.

In the future, some of the efforts to address transboundary issues will investigate the areas described below as possible sources of data for indicators:

- Emissions of other greenhouse gases can be tracked based on statewide methane and nitrous oxide emissions data from the California Energy Commission's greenhouse gas inventory report, which is expected to be released in 2002.
- The Pacific Ocean plays a role in determining California's onshore air temperatures through the eastward movement of air masses, which have been affected by ocean water temperatures. Air temperature data from an array of land weather reporting stations and sea surface temperatures off the California coast can be correlated to reflect the ocean's influence on calculations of climate change.

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- Additional climate change indicators to be explored include trends in soil moisture, precipitation intensity, windiness, sea wave height and intensity, Pacific Ocean current patterns, and changes in plant blooming cycles (such as those of the lilac and honeysuckle) and in animal and insect migrations.
- California emissions of hydrochlorofluorocarbons (HCFCs) for ozone depletion and hydrofluorocarbons (HFCs) for global warming can be estimated from an emissions inventory of reported substances.
- The SWRCB monitors water from the Tijuana River, which flows northward from Tijuana into San Diego, and the New River, which flows northward from Mexicali into Calexico and the Salton Sea, for pathogens and pollutants. Less than one-quarter of the total flows in these rivers is related to sewage outflows, but much of it is untreated. New sewage treatment plants are being constructed to address this problem. Additional contaminants enter the river from agricultural returns. Indicators based on these monitoring data will track the progress of the river cleanup efforts.
- The suitability of data on the movement of hazardous wastes across the border will be investigated for potential indicator development. Hazardous wastes are transported to and from California either as usable "products," or as wastes destined for treatment or disposal. At the border crossing, the number of trucks carrying waste is tallied daily, and monthly random truck inspections are conducted at Tijuana, Otay Mesa, and Mexicali. The hazardous wastes are most commonly generated from the textile, metal plating, and electronic industries.
- At present, there is a 90 percent rate of compliance with regulatory requirements for mid-ocean exchange of ballast water by ships entering California ports. Although the exchange will decrease the likelihood of non-indigenous aquatic species entering California waters, the efficacy of the ballast water transfer, species characterization, and the role of bottom paint on the hull of vessels are being studied.

Human Health

The health of Californians is generally very good and improving, in terms of longevity and quality of life. Infant mortality rates continue to decrease, from almost 8 deaths per 1,000 live births in 1990 to slightly more than 5 deaths per 1,000 live births in 1999. The life expectancy of Californians continues to increase, and compares favorably to national averages. In 1997, life expectancy at birth was 75.5 years for males and 80.7 years for females in California, compared to 73.6 years for males and 79.4 years for females nationally. However, certain health conditions, including asthma, have been reported to be increasing in frequency over the course of the years, for reasons not yet well understood.

Cal/EPA programs aim to control the presence of harmful chemicals in the environment, and to ensure that sensitive or highly exposed groups are protected from exposures that may lead to adverse health effects. Protecting human health is the underlying basis for many regulatory environmental standards. Hence, many of the indicators in the other sections of the report relate to human health. The indicators in the human health section are those that reflect the impacts of exposures to environmental contaminants on people. These indicators will assist Cal/EPA in understanding how its efforts to protect the public from environmental pollutants are influencing human health. One indicator which can directly be attributable to environmental pollution is the presence of lead in children's blood at elevated levels (10 micrograms per deciliter or higher). Humans can retain, or bioaccumulate, chemicals in their bodies over time. These chemicals can have delayed adverse effects, and thus represent a potential health threat. Currently, lead is the only bioaccumulated substance for which levels in children are reported to the state, when they exceed the standard. Presently, only two facilities report blood lead levels for all children tested. However, these data are not necessarily representative of blood lead levels in the California population; thus no trends can be presented.

Future efforts related to developing these indicators are described below:

- Potential bioaccumulative chemicals that need to be addressed with indicators include persistent organic

pollutants and inorganic chemicals such as lead and mercury.

- Environmental pollutants are known to influence the disease process, yet their impacts on human health are difficult to quantify. Besides environmental exposures to pollutants, many factors influence the disease process, including genetics, lifestyle choices and aging. All of these contribute to specific human health conditions and diseases, making the development of human health indicators of environmentally-related effects challenging.

- More monitoring data on human disease conditions that may be related to environmental contaminants are needed. Many diseases and conditions are monitored through programs of other agencies and related entities. However, it is not always clear from the available data whether occurrences of adverse health effects are related to exposure to environmental chemicals. Careful surveillance of disease conditions may lead to a better understanding of environmental influences. Recently enacted legislation (Senate Bill 702, Chapter 538, Statutes of 2001) requires a study on the feasibility of developing an environmental health surveillance system for the state. Specific research is needed to better characterize environmental contributions to existing disease rates.

There is always the possibility that some diseases and conditions affected by environmental contamination go unnoticed or are difficult to quantify. With advancements in medical science, environmental associations with disease will be better understood. Cal/EPA programs will use this knowledge in continued efforts to minimize human exposures to potentially harmful pollutants.

Ecosystem Health

Protection of the environment and natural resources is the focus of much of the work at Cal/EPA and the Resources Agency. The primary issues facing these agencies are preserving adequate quantity and quality of habitat, biodiversity, and ecosystem function, while making use of California's abundant and unique natural resources. There are relatively few data sets available for developing indicators of ecosystem health. In many instances, the data needed to support the development of the indicators in this area are in the process of being collected, are collected in an incomplete manner, or are not collected at all. At this time, limited conclusions about the health of the state's ecosystems can be drawn from the available data.

Quality and quantity of habitat

There is significant pressure for the conversion of natural landscapes to more human-oriented uses, such as irrigated agriculture and residential uses. It has long been recognized that degradation of habitat, including fragmentation into small, disconnected pieces, is a key factor in the reduction of ecosystem integrity. Some ecosystems are more sensitive than others and ecosystems in certain regions of the state have greater environmental value than others. The indicators in this report suggest the following:

- An average of 45,000 acres per year are being converted from farmland and rangeland to urban and other uses. Agricultural land falls into the "working landscape" category, preserving varying degrees of ecological value, providing open space, and providing crucial capital for agriculture.

- In the past 15 years, about 1.1 million acres of the 1982 base acreage of forest and rangeland have been converted to other uses. These lands also fall into the working landscape category, but often have a higher degree of ecological integrity than farmland.

- Nineteen percent of California lands are managed to maintain a high degree of ecological integrity, such as parks. An additional 64 percent are working lands which, while managed for some degree of production, continue to provide important wildlife habitat. The remaining lands have been significantly transformed by human activities.

Biodiversity

The indicators for the diversity and abundance of California's plants and animals show the following:

- Little is known about the status of populations of threatened and endangered species (TES). Fewer than 5 percent of threatened and endangered plant species, and about 15 percent of animal species have increasing

populations. The population trends for about 20 percent of TES plants and 35 percent of animals are unknown.

- The population of winter- and spring-run chinook salmon in the Central Valley, one of the TES for which reasonably good information exists, continues to decline to very low levels.
- The population of the least tern, a coastal shorebird, appears to be stable at present.
- The population of the threatened desert tortoise is decreasing, suggesting that human activities continue to have a negative impact on the species.
- In two important forested areas that cover the Sierra and Cascade mountain ranges along the eastern portion of the state, the extent of both hardwood and conifer tree canopy has increased.
- The population of the Northern Spotted Owl along the north coast appears to be holding steady at 2,300 breeding pairs. Future reports will include an assessment of the status of California spotted owl populations in various regions of the state.

Ecosystem Function

Developing indicators for ecosystem function was a challenging endeavor. Identifying the appropriate measures of ecosystem function is difficult, and once identified, finding data to support the indicator has proven nearly impossible.

- In this first report, a single measure of ecosystem function is presented – the clarity of Lake Tahoe. Lake clarity, a measure of eutrophication or nutrient loading and sedimentation, reflects many processes that occur within a lake system. One of the reasons that it is an excellent indicator is that it captures multiple ecological processes of the lake, therefore reflecting significance beyond the simple measurement of clarity. The decrease in clarity of Lake Tahoe over the past 30 years suggests that the healthy ecological functions in this lake are declining. Information on additional lakes in different regions of the state will be investigated for future reports.
- The Stream Invertebrate Bioassessment Program, a joint effort of the California Department of Fish and Game and the U.S. Environmental Protection Agency, will provide information on the health of streams throughout the state. Measurements of the abundance and diversity of benthic invertebrates living in the streambed broadly reflect the status of a variety of ecological processes within each stream.
- There is a need for additional information on the status of natural resources for all California ecosystems. Most data collection efforts to date have been reactive, focusing on "hot-spots" such as spills of toxic chemicals, reports of fish kills, effects of building a new road, or other specifically targeted activities. In order to develop indicators that reflect the status and trend of the state's ecosystems, scientifically-based monitoring is needed. Without such monitoring data, more accurate and inclusive indicators cannot be developed.

In some areas, little if any information is presently available for indicator development. These are identified as Type III indicators or data gaps:

- While frog deformities and deaths have been documented throughout the nation, scant information is available on the status of amphibian populations in California.
- Significant national efforts are underway at the U.S. Environmental Protection Agency and elsewhere to understand the effects of endocrine disrupting chemicals on wildlife. In particular, treated wastewater has been shown to cause harmful effects on fish, including salmon. Information on the presence of such chemicals in California's waters needs to be collected.
- Data on non-native invasive species in specific ecosystems are needed. This issue is also addressed in the "Transboundary Issues" section.
- Persistent organic pollutants, known to cause reproductive harm and cancer, have been found in marine mammals throughout the world. These organic pollutants include pesticides and industrial chemicals that have been banned for many years, as well as emerging problem chemicals. Monitoring of seals, as

suggested by the "persistent organic pollutant in harbor seals" indicator in this report, could signal the presence of problematic levels of such chemicals in aquatic ecosystems.

- Data on agricultural ecosystems are presently available, but coordination with other state agencies with agricultural expertise is needed to develop information in a form useful for indicators. Agriculture faces significant challenges, including falling commodities prices, increased global competition, and increasing demands for water and land by a growing urban population. Agriculture has played an important economic and historical role in California, and in many cases, there are positive environmental benefits within agricultural land use practices. Development of indicators of agroecosystem health will be a focus of future reports.
- Urban ecosystem indicators are also sparse in the report. Similar to agro-ecosystem indicators, partnerships need to be formed to develop appropriate indicators in this area. One of the future challenges is to identify and develop measures of urban habitat sustainability and quality of life.

What direction should the development of ecological indicators take in the future? How can these efforts be combined with those of others to better characterize the state's ecosystem health, and this information used to allocate resources and develop policy on natural resource and environmental protection? Efforts in the following areas will help address these questions.

- A regionally-based and statistically-robust program of long-term ecosystem monitoring is needed. This effort could focus on identifying particularly sensitive ecological areas. The Nature Conservancy has already taken initial steps in this effort. A network of representatives from the Resources Agency, Cal/EPA, federal agencies, and non-government organizations could meet periodically to coordinate efforts and help identify ecosystem monitoring priorities. Such an effort might be done in collaboration with the California Legacy Project at the Resources Agency.
- The Organisation for Economic Co-operation and Development has proposed the development of a natural capital index for biodiversity. This measurement integrates information on habitat quality, quantity, and species richness and abundance. If specific information is not available on the population status of a species, which is the case for many threatened and endangered species in California, data on ecosystem pressures can be substituted. The feasibility and value of such an index for California will be explored in the future.
- Although this report contains significant information on the extent of forest and rangelands, the relationship between these indicators and wildlife biodiversity is not clear. Future efforts will explore the feasibility of developing such an indicator.
- An obvious omission in the ecosystem health indicators is the lack of an indicator for the status of wetlands and marine resources. The Bay Institute of San Francisco (www.bay.org), the San Francisco Estuary Program (www.sfei.org), and Western Center for Estuarine Ecological Indicators at Bodega Bay Marine Labs are working on developing indicators for the Bay Delta, its watershed, and the estuary.
- There is a need for analysis of changes in habitat quantity across the state for all ecosystems. Without a quantitative assessment, decisions will be based on incomplete and potential incorrect information. This is one of the goals of the California Legacy Program.

Future Directions for the EPIC Project

The EPIC Project is intended as a continuing effort to produce and maintain an environmental indicator system for California that conveys meaningful information about key environmental issues in the state, and that serves a critical role in the decision-making processes in environmental programs. The initial set of indicators serves as the starting point for the EPIC Project's efforts to evaluate, validate, enhance and expand California's environmental indicator system. As part of its future efforts, the EPIC Project will:

FINDINGS

- Enhance collaborations with the Resources Agency, the Department of Health Services, and other entities in order to develop a more integrated and coherent environmental reporting mechanism for the state.
- Review the existing issues to ensure that all pertinent areas are covered. The review will focus both on the issues themselves and what they cover, as well as new areas not currently included. Possible areas of expansion include issues dealing with environmental policies, such as sustainability, environmental justice, and pollution prevention.
- Explore alternative ways of organizing the issues so that the interrelationships among them are more evident. Presently, issues have been largely defined based on areas of regulatory responsibility (e.g., air pollution, water quality and others). A better understanding of the interrelationships may improve the formulation of solutions to environmental problems, and promote more coordinated monitoring and data collection.
- Use geographic information systems (GIS) to analyze and present different types of information for a defined geographic area. GIS is a computer-based tool for managing and presenting multiple geographically-based data, providing new perspectives and understanding on environmental and natural resource issues.
- Develop regional indicators, where needed to convey more meaningful information about environmental conditions.
- Improve existing indicators based on new scientific knowledge, analytical capabilities, or regulatory changes, and update indicators as new data become available. The EPIC report will be published on a regular basis (every two years, or as necessary).
- Work with those responsible for strategic planning, policy formulation and budgeting to assess and enhance the utility of the indicators in decision-making. By evaluating and characterizing the factors that can influence the trends in an environmental indicator, the impact of environmental programs in effecting a desired change in an indicator can be better understood.
- Coordinate with the Emerging Environmental Challenges Program in the Office of Environmental Health Hazard Assessment to explore ways by which the environmental indicators can be used to identify and characterize future environmental challenges and, conversely, develop appropriate indicators for issues that have been identified as emerging challenges.
- Strengthen and expand partnerships with those who have an interest in California's environment, including local government agencies, community organizations and the regulated community, in working toward sustainability goals. These partnerships will facilitate the sharing of data, information and resources, and promote the setting of shared goals and priorities.
- Promote public awareness of environmental issues using indicators as tools for communicating information, and initiate dialogue with interested parties to invite input. This will be accomplished by convening regional meetings, publishing materials geared to a broad audience with information drawn from this report, and popularizing the EPIC web site (www.oehha.ca.gov) which will include links to data sources, and electronic mailing lists.

The EPIC Project is an aggressive undertaking to better understand what is happening in the environment in order to find effective ways of preserving and improving it. This undertaking is still in its formative stage. The process for identifying and developing indicators has been established, and an initial set of indicators presented, but much work remains to be done. In the end, pursuing the development of meaningful, well-founded environmental indicators will yield substantial rewards for California by optimizing the efforts of its environmental and natural resource programs.